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(54) Combined gas-air control system for controlling combustion in gas fired boilers

(57) The combined gas-air control system for gas fired boilers (B) including a microcontroller (µC) with memory means, set point temperature selector means (R_h,R_s), measuring means (18,19,20,21), a thermostat (27), a variable-speed fan (6), a gas modulating valve (MV) in which the microcontroller (µC) comprises: first controlling means (22) for correcting the error signal $E(T)=Trh-T_h$ or $E(T)=Trs-T_s$ and for controlling the air pressure in the combustion chamber (1), second controlling means (23) for correcting the error signal $E(P)=P_{ac}-P_a$ and for controlling the speed of the fan, processing means (24,25) for processing the ionisation voltage and the modulating valve current signals, third controlling means (26) for correcting the error signal $E(V)=V_{ion(th)}-V_{ion}$ and the modulating valve current.

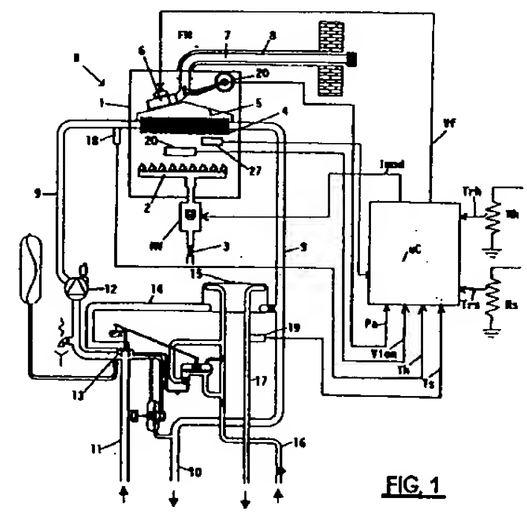

FIG. 1

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Description

[0001] The present invention relates to automatic control systems for controlling the gas and/or air flow rates in gas fired boilers using an ionisation electrode as a sensing element for determining the combustion condition of the burner.

[0002] New standards regarding gas fired boilers are limiting the allowable emissions of harmful products resulting from combustion, specifically CO and NOx, to a very low level.

[0003] In order to respect the new standards, improvements in the combustion process in gas fired boilers have proved to be necessary. Therefore, several manufacturers have provided their gas fired boilers with automatic control systems by which optimal operation of the burner in any condition of thermal load can be ensured.

[0004] The most common method of monitoring the combustion process is to utilize an ionisation electrode arranged in the flame area of the burner. It is known that the current flowing through this electrode, i.e. the ionisation current, depends upon the combustion conditions. Thus, information on the actual combustion condition is obtained by directly measuring the ionisation current or by measuring the voltage across the electrode which is a function of said ionisation current. The control system measures the ionisation current and derives therefrom a signal to be used as a control variable for controlling the flow rate of at least one of the combustion components, namely air and gas, supplied to the gas fired boiler.

[0005] The present invention relates to an automatic control system for controlling both the gas and air flow rates in gas fired boilers. This automatic control system will be referred to in the description as "combined gas-air control system".

[0006] More particularly, the combined gas-air control system for gas fired boilers comprises:

- a microcontroller with memory means,
- selector means for predetermining set point temperatures T_{rh},T_{rs} of the heating and sanitary water respectively,
- measuring means for ascertaining the temperature of the heating T_h and sanitary T_s water, the air pressure P_a in the combustion chamber and the ionisation voltage V_{ion} in the flame area of the burner, respectively and for communicating the measured values back to the microcontroller,
- a thermostat for monitoring operation of the burner and for preventing its overheating,
- a fan operated by a variable-speed motor for controlling the flow rate Q_a of air supplied to the combustion chamber,
- an electrically controlled modulating valve for modulating the flow rate Q_g of gas supplied to the burner, characterized in that said microcontroller comprises:
- first controlling means for producing a corrective action in response to an error signal $E(T)=T_{rh}-T_h$ or $E(T)=T_{rs}-T_s$ and for giving an output signal P_{ac} corresponding to a corrected value of air pressure in the combustion chamber,
- second controlling means for producing a corrective action in response to an error signal $E(P)=P_{ac}-P_a$ and for adjusting the control voltage V_f applied to the variable-speed motor,
- processing means for calculating theoretical optimal values of the ionisation voltage and the modulating valve current in response to the output signal P_{ac} from said first controlling means and for giving said theoretical values as output signals $V_{ion(th)}$ and $I_{mod(th)}$, respectively,
- third controlling means for producing a corrective action in response to an error signal $E(V)=V_{ion(th)}-V_{ion}$ and for giving an output signal I_{modc} corresponding to a corrected value of the modulating valve current, said output signal I_{modc} from said third controlling means being added to the output signal $I_{mod(th)}$ from said processing means and the resulting sum signal $I_{mods}=I_{modc}+I_{mod(th)}$ being applied to the modulating valve.

[0007] The combined gas-air control system will be described in more detail with reference to the accompanying drawings, wherein:

Figure 1 is a schematic view of a gas fired boiler provided with the combined gas-air control system of the present invention, and
Figure 2 is a block diagram of the combined gas-air control system according to the present invention.

[0008] Figure 1 shows a gas fired boiler, generally indicated with B, comprising an airtight combustion chamber 1 in which a gas burner 2 is arranged and gas supplied via an ON-OFF valve 3 mounted on the gas supply pipe. An electrically controlled modulating valve MV is arranged downstream from the ON-OFF valve 3 for the purpose of modulating the gas flow rate. A finned heat exchanger 4 is placed above the gas burner 2. Overhead the gas burner 2 and the heat exchanger 4 a hood 5 is provided with a suction fan 6 for drawing fumes from the combustion chamber and expelling them via an exhaust pipe 7. The suction fan 6 also sucks ambient air from the outside via a suction pipe 8 arranged coaxially to the pipe 7 and supplies it to the combustion chamber 1 in order to sustain the combustion. The fan 6 is operated at adjustable speed by means of a variable-speed motor FM.

[0009] A pipe 9 forming the heating circuit (primary circuit), passes through the heat exchanger 4 for heating the heating water (primary heat exchanger). The heating water is supplied via a delivery pipe 10 and returns to the gas fired boiler via a return pipe 11. The pipe 9 embodies a circulation pump 12 and a three-way valve

13. A pipe 14 forming the circuit for the sanitary water (secondary circuit) and passing through the heat exchanger 15 for heating the sanitary water (secondary heat exchanger) departs from the three-way valve 13. Sanitary water is supplied to the secondary heat exchanger 15 via a pipe 16 and after being heated it is delivered via a pipe 17 for usage.

[0010] The function of the combined gas-air control system of the invention is to control the gas and air flow rates in the gas fired boiler B in order to hold either the heating water temperature or the sanitary water temperature to a desired value which will be referred to in the following as set point temperature.

[0011] Another function of the combined gas-air control system of the invention is to improve combustion and reduce emission of harmful combustion products in gas fired boilers.

[0012] In order to accomplish this, the combined gas-air control system of the invention comprises a microcontroller μC for operating the modulating valve MV and for adjusting the speed of the variable-speed motor FM. The output control signals transmitted from the μC to the modulating valve MV and the variable-speed motor FM are indicated with I_{mod} and V_f and they correspond to the control current of the modulating valve MV and to the control voltage of the variable-speed motor FM, respectively.

[0013] In response to the control signals I_{mod} and V_f transmitted from the μC to the modulating valve MV and the variable-speed motor FM, the gas flow rate Q_g and the air flow rate Q_a are controlled so as to change combustion process conditions in the gas fired boiler B and to bring the heating or sanitary water temperature back to the set point predetermined by the user. Q_g and Q_a will be referred to in the following as manipulated variables.

[0014] The set point temperatures of the heating and sanitary water are set typically by means of potentiometers R_h and R_s, respectively and the corresponding set point input signals T_{hr} and T_{sr} are supplied to the microcontroller μC. Feedback informations relating to the heating water and sanitary water temperatures, the air pressure in the combustion chamber 1 and the combustion process conditions in the burner 2 are sensed by appropriate sensors and transmitted to the microcontroller μC. To accomplish this, temperature measuring means 18, 19 embodying standard temperature sensors are provided for measuring the heating water and the sanitary water temperatures, respectively, air pressure measuring means 20 embodying a standard pressure sensor are provided for measuring the air pressure in the combustion chamber, and an ionisation electrode 21 arranged in the flame area of the burner is provided for measuring the voltage across the ionisation electrode as a function of the ionisation current through the ionisation electrode depending on the combustion process conditions of the burner 2. The feedback signals transmitted from the measuring means 18, 19, 20 and 21 to the microcontroller μC are indicated with T_h, T_s, P_a and V_{ion} respectively.

OPERATION

[0015] Operation of the combined gas-air control system will be now described with reference to the block diagram of Figure 2.

[0016] According to the usual conventions, lines represent signals, a circle is an algebraic summing point representing addition or subtraction of input signals to the point, rectangles are system elements and a line branching from another line indicates a division of the signal into more than one path without modification.

[0017] The controlled variables are the heating and the sanitary water temperatures, the air pressure in the combustion chamber and the voltage across the ionisation electrode. Feedback signals T_h, T_s, P_a and V_{ion} proportional to the values of the controlled variables are applied to the microcontroller μC for processing. Control signals V_f and I_{mod} from the microcontroller μC are transmitted to the variable-speed motor FM and the modulating valve MV and control of the manipulated variables Q_a and Q_g in response to said control signals is thereby obtained.

[0018] Operation of the system can be seen considering the control of the sanitary water temperature, but it should be clearly understood that a similar operation applies to the control of the heating water temperature.

[0019] Referring to Figure 2, the microcontroller μC compares the feedback signal T_s from the water temperature measuring means 18 with the set point signal T_{rs} and transmits their difference, i.e. the error signal $E(T)=T_{rs}-T_s$, to the control element 22 which utilizes said error signal E(T) to determine the corrected value of air pressure in the combustion chamber 1. The control element 22 in response to the error signal E(T) sequentially performs a proportional+integral+derivative (PID) control mode and a proportional (P) control mode. The output signal P_{ac} resulting from this PID and P corrective action is compared with the feedback signal P_a from the air pressure measuring means 20 and the error signal $E(P)=P_a-P_{ac}$ actuates the control element 23. Said control element 23 performs in sequence a PID control mode and P control mode and adjusts the control voltage V_f applied to the variable-speed motor FM so as to change the manipulated variable Q_a, i.e. the air flow rate, in response to the error signal E(P).

[0020] The output signal P_{ac} from the control element 22 is also applied to processing elements 24 and 25 which calculate the theoretical values of the voltage across the ionisation electrode and of the modulating valve current dependent on the corrected air pressure value. In order to accomplish this calculation, each processing element 24 and 25 embodies a memory in which the optimal relationships between the voltage across the ionisation electrode and the modulating valve current, respectively and the air pressure in the

combustion chamber are stored. The output signals from the processing elements 24 and 25 are indicated with $V_{ion(th)}$ and $I_{mod(th)}$, respectively.

[0021] The feedback signal V_{ion} from the ionisation voltage measuring means 21 is compared with the output signal $V_{ion(th)}$ from the processing element 24 and the error signal $E(V)=V_{ion(th)}-V_{ion}$ is supplied to the control element 26. In response to the error signal E(V), the control element 26 performs a P control mode and determines a corrected value of the control current in the modulating valve MV. The output signal I_{modc} from the control element 26 is added to the output signal $I_{mod(th)}$ from the processing element 25 and the resulting sum signal $I_{mods}=I_{modc}+I_{mod(th)}$ is used to operate the modulating valve MV so as to change the manipulated variable Q_g, i.e. the gas flow rate.

[0022] Operation of the burner is also monitored by a thermostat 27 arranged in the burner area and connected to the µC. In the case of burner overheating, the thermostat 27 signals the malfunctioning to the µC which then shuts down the burner.

[0023] Essentially, the rpm of the fan motor and the modulating valve current can be adjusted for ensuring the required air Q_a and gas Q_g flow rates according to the set point temperatures of the heating or sanitary water that is delivered to usage. When the thermal load changes, a change in the rpm of the fan motor and in the throttle of the modulating valve will occur. Moreover, operation of the burner is also automatically adjusted when the type of gas supplied to the burner changes. The combined gas-air control system of the invention ensures optimal operation of the gas fired boiler with respect to NOx and CO emissions and efficiency.

Claims

1. Combined gas-air control system for gas fired boilers (B) including:

   - a microcontroller (µC) with memory means,
   - selector means (R_h,R_s) for predetermining set point temperatures (T_{rh},T_{rs}) of the heating and sanitary water respectively,
   - measuring means (18,19,20,21) for ascertaining the temperature of the heating (T_h) and sanitary (T_s) water, the air pressure (P_a) in the combustion chamber (1) and the ionisation voltage (V_{ion}) in the flame area of the burner (2), respectively and for communicating the measured values back to the microcontroller (µC),
   - a thermostat (27) for monitoring operation of the burner and for preventing its overheating,
   - a fan (6) operated by a variable-speed motor (FM) for controlling the flow rate (Q_a) of air supplied to the combustion chamber (1),
   - an electrically controlled modulating valve (MV) for modulating the flow rate (Q_g) of gas supplied to the burner (2),

   characterized in that said microcontroller (µC) comprises:

   - first controlling means (22) for producing a corrective action in response to an error signal $E(T)=Trh-T_h$ or $E(T)=Trs-T_s$ and for giving an output signal P_{ac} corresponding to a corrected value of air pressure in the combustion chamber (1),
   - second controlling means (23) for producing a corrective action in response to an error signal $E(P)=P_{ac}-P_a$ and for adjusting the control voltage V_f applied to the variable-speed motor (FM),
   - processing means (24,25) for calculating theoretical optimal values of the ionisation voltage and the modulating valve current in response to the output signal P_{ac} from said first controlling means and for giving said theoretical values as output signals $V_{ion(th)}$ and $I_{mod(th)}$, respectively,
   - third controlling means (26) for producing a corrective action in response to an error signal $E(V)=V_{ion(th)}-V_{ion}$ and for giving an output signal I_{modc} corresponding to a corrected value of the modulating valve current, said output signal I_{modc} from said third controlling means (26) being added to the output signal $I_{mod(th)}$ from said processing means (25) and the resulting sum signal $I_{mods}=I_{modc}+I_{mod(th)}$ being applied to the modulating valve (MV).

2. Combined gas-air control system according to claim 1, characterized in that the corrective action of said first (22) and second (23) controlling means in response to the respective input error signals E(T) and E(P) embodies in combination a proportional+integral+derivative control mode and a proportional control mode.

3. Combined gas-air control system according to claim 1, characterized in that the corrective action of said third controlling means (26) in response to the input error signal E(V) embodies a proportional control mode.

4. Combined gas-air control system according to claim 1, characterized in that in said microcontroller (µC) the optimal relationships between the voltage across the ionisation electrode and the modulating valve current,respectively and the air pressure in the combustion chamber are stored.

5. Combined gas-air control system according to claim 1, characterized in that said microcontroller (µC) is preferably a digital microcontroller provided with standard A/D and D/A conversion means.

6. Combined gas-air control system according to

claim 1, characterized in that said third controlling means (26) provide for an automatic adjustment of the burner operation when the type of gas supplied to the burner changes.

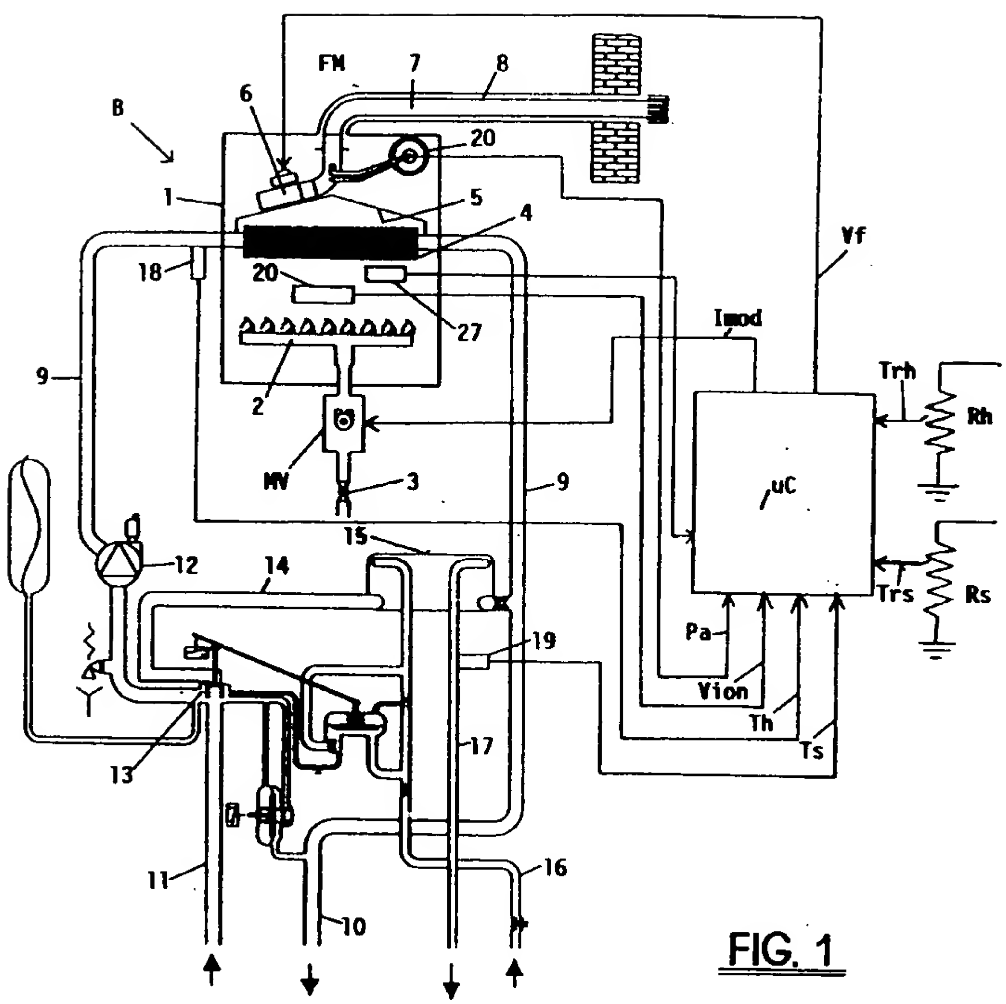
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FIG. 1

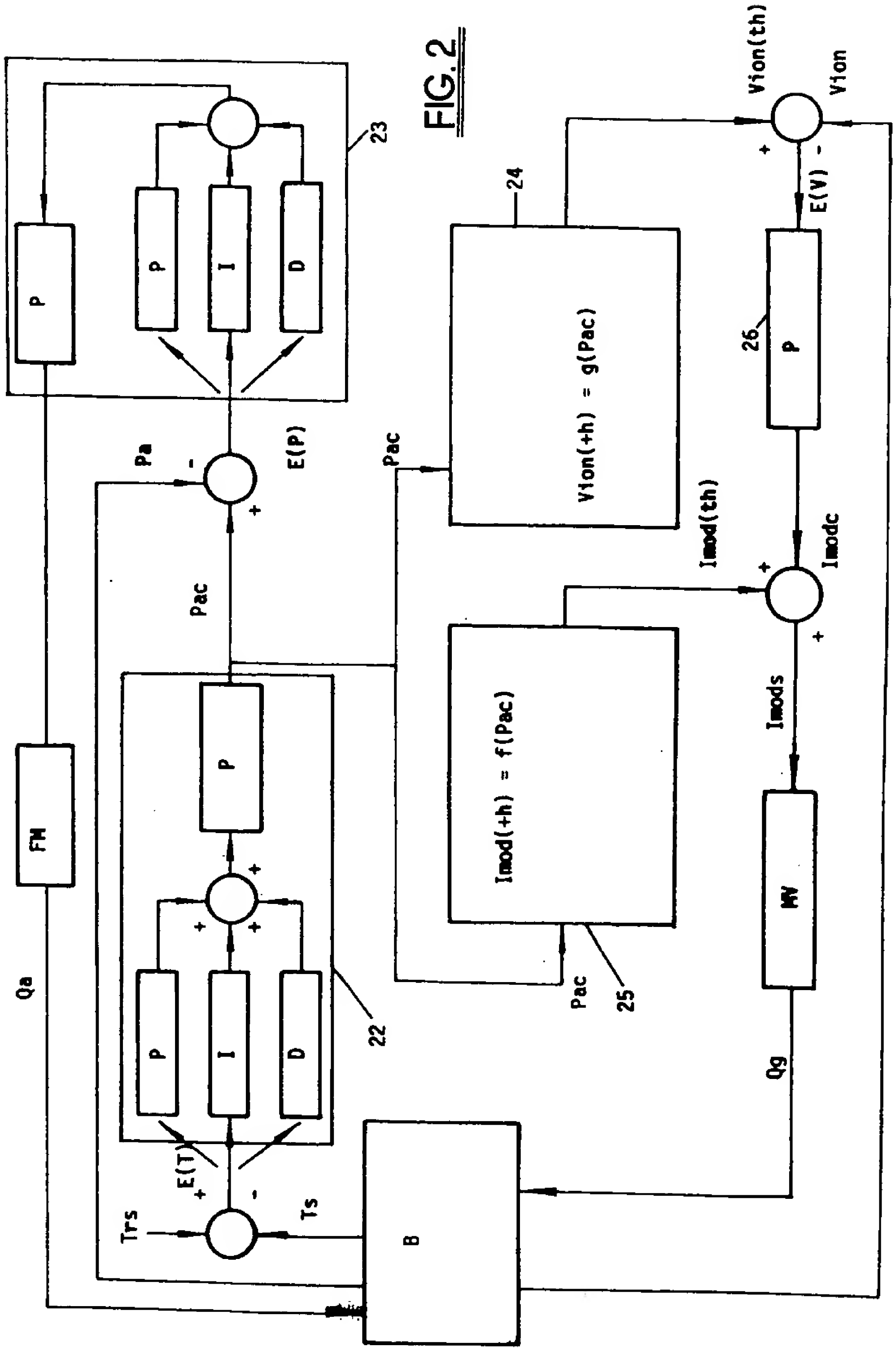
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FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 97 83 0520

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 429 034 A (VAILLANT) * the whole document * ---	1	F23N5/12 F23N1/10
A	DE 196 18 573 C (STIEBEL ELTRON) * the whole document * ---	1	
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A	PATENT ABSTRACTS OF JAPAN vol. 095, no. 006, 31 July 1995 & JP 07 071748 A (GASTAR CORP), 17 March 1995, * abstract; figure * ---	1	
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A	PATENT ABSTRACTS OF JAPAN vol. 014, no. 416 (M-1021), 7 September 1990 & JP 02 161208 A (HARMAN CO LTD), 21 June 1990, * abstract; figure * -----	1	F23N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 February 1998	Kooijman, F

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